## 3.6.3. Dynamic Non-maneuvering Position Accuracy

### 3.6.3.1. Purpose

The purpose of this test is to measure the dynamic, non-maneuvering position accuracy of the GPS/INS, GPS alone and INS alone and to isolate the effects of non-maneuvering flight upon the INS and GPS, and finally to qualitatively assess the utility of the INS as a navigation aid in the non-maneuvering environment.

### 3.6.3.2. General

Static testing provided a baseline of accuracy over time caused by errors inherent to the INS platform, accelerometers and gyroscopes and the GPS unit. Dynamic non-maneuvering position accuracy testing provides the next logical step in fully testing the INS and GPS both coupled and alone. While airborne, the aircraft is flown on navigation profiles designed to demonstrate the effects of aircraft movement during flight while minimizing any maneuvering.

For configurations where the INS is used, the profiles are flown over maximum north-south and east-west distances to excite the effects of earth rate and the Coriolis force. The flight duration should be equal to the maximum mission duration or two Schuler cycles, whichever is shorter. The optimum technique is to perform one flight on a predominately east-west profile and one on a predominately north-south profile repeating as necessary to establish the required statistical baseline. The maximum cruise range speed should be used to allow the maximum latitude and longitude to be covered.

The coupled GPS/INS is a highly accurate navigation system. This strength makes it extremely hard to test system accuracy while simultaneously navigating over long ranges, since the theodolite and laser ranger techniques described earlier are usually restricted to local testing. The long north-south and east-west legs are necessary for the coupled system since the INS dynamics described in the INS theory section can still cause system errors. Thus, it must be conceded that it is not practical to test the GPS/INS to within the expected system SEP. However, it is possible to verify that the system provides the accuracies necessary to perform the mission throughout the flight profile and to spot check the absolute accuracy at various points during the test. As part of the test to be described here, a separate, portable GPS is used to provide a relative position accuracy comparison during the long legs. This is not the optimum situation since it does not verify the absolute accuracy of the test unit, merely the accuracy relative to another GPS which can theoretically have similar errors. As a minimum, the absolute accuracy is verified at the start and at the shut down of the system. In addition, where possible, the flight profiles are planned to allow flight in the vicinity of a facility capable of providing the highly accurate theodolite or laser tracker space positioning data.

When the GPS is running alone, the system errors are not driven by the INS dynamics and the need to cover rigid flight profiles is lessened, allowing the system to be flown in the vicinity of a space positioning facility. The GPS position is thus compared to the accurate space positioning data at frequent times during the flight. For the case where the INS is run alone, the test is conducted identically to the dynamic non-maneuvering test described previously in the INS testing section. Since the expected accuracy of the INS system alone is much less than the coupled system or the GPS system alone, the flyover method is adequate.

### 3.6.3.3. Instrumentation

A portable GPS receiver, stop watch and data cards are required for this test, a voice recorder is optional. A properly instrumented range including highly accurate laser ranger or theodolite tracking is required. For the case where a laser ranger is used, a laser reflector array must be installed on the test aircraft.

### 3.6.3.4. Data Required

For the configuration where the GPS and INS are available and coupled, after recording the initialization and alignment data, record the displayed latitude and longitude as a navigation mode is selected. Record the GPS/INS and portable GPS latitude and longitude; the satellites used, their quality numbers and the total fix quality number; also record the GPS/INS and portable GPS altitude, course and groundspeed, all at five-minute intervals. At each laser ranger or theodolite flyover point, record the elapsed time, point identification, altitude, GPS/INS displayed latitude and

longitude, satellites used, satellite quality numbers, total fix quality number, altitude, course, groundspeed and laser or theodolite calculated latitude and longitude, altitude, course and groundspeed. After the taxi back to the hangar, record the surveyed parking location, elapsed time and GPS/INS displayed latitude and longitude. Throughout the flight, record as notes on the data cards, any maneuvers requiring over 1.5 g, 30° angle of bank, or 20° of pitch, any airspeed changes of over 50 KIAS (other than takeoff and landing) and any INS or GPS system alerts, along with the elapsed time of occurrence. Record qualitative comments concerning the utility of the GPS/INS in navigating to each waypoint along the route.

Record the same data for the GPS-alone test condition, deleting the INS alerts. Repeat both tests with the P code not installed. When using the INS alone, record the data described in the INS test procedures presented earlier.

**3.6.3.5. Procedure**

For the case of the coupled GPS/INS, prior to the test flight, plan a route that provides a flyover of as many accurate space positioning ranges as possible. Plan at least one flight predominately east-west and one north-south. Choose a flight profile consistent with normal, long range cruise.

Perform an Initialization and Alignment test as previously outlined. When the alignment is complete, select a navigation mode, start the stop watch and then record the displayed latitude and longitude. At five-minute intervals, record the elapsed time along with the GPS/INS and portable GPS positions, satellites used and the quality numbers described in the data section. Record any system alerts with the elapsed time as notes.

Perform a normal airfield departure, navigating to the initial waypoint. Select an airspeed near the maximum range airspeed at the test altitude and set this airspeed as early as possible. Attempt to maintain this airspeed throughout as much of the flight as possible. Care must be taken to limit maneuvering. Keep g, pitch and bank to a minimum, recording the elapsed time and a complete description of all deviations. Generally, anything over 1.5g, 30° angle of bank, 20° of pitch or 50 KIAS of airspeed change should be noted.

While navigating to the waypoints, evaluate the utility of the GPS/INS displays/controls, utility of the GPS/INS derived steering cues, as well as the integration of the navigation information within the aircraft as a navigation aid in the non-maneuvering environment.

When flying over the precise space positioning sources, record the same data required for the five-minute data points in addition to the theodolite or laser ranger derived positioning data.

Following touchdown and rollout, taxi to a surveyed parking area. Before shutdown, record the elapsed time and displayed latitude and longitude.

Repeat the test for the case where the GPS is used alone. The entire flight may be performed in the vicinity of a space positioning range. Repeated laser ranger or theodolite fixes at 5 to 15-minute intervals are required. Repeat the first two tests without the P code installed.

For the condition where the INS is used alone, perform the test as outlined in the INS test procedure section.

**3.6.3.6. Data Analysis and Presentation**

Subtract the coupled GPS/INS displayed latitude and longitude from the surveyed point latitude and longitude or precise space positioning derived latitude and longitude, as appropriate. Convert the latitude and longitude difference to nm using equation (21). Plot the data as latitude and longitude error versus elapsed time. Annotate the plots with any significant events noted during the test, such as system alerts or maneuvering above 1.5g, 30° angle of bank, 20° of pitch or airspeed changes of 50 KIAS. Apply the same procedure to the GPS/INS and the portable GPS-derived positions and add to the same plot using different symbols.

Develop similar plots comparing the GPS/INS altitude, course and groundspeed and the data collected from the space positioning data and the hand-held GPS.

Analyze the trend of the plots for the possible causes of the errors. If the start-up and shut-down surveyed points and the precise space positioning data points show little error for the

portable GPS, assume that the portable GPS may be used as a truth data source for the times between the absolute fixes. Typically, the GPS will provide such precise updates at such frequent intervals that the INS errors discussed in the INS section will not be evident.

Since the time dependent errors of the INS are not easily seen in the coupled system, it is also useful to develop a scatterplot as defined in the OMEGA section to highlight any errors caused by the position fixing GPS receiver.

Relate the non-maneuvering accuracy of the coupled GPS/INS to the requirement to perform non-maneuvering navigation during ferry missions and while ingressing from the base airfield to enemy lines.

If excessive maneuvers are recorded during the flight, check for significant changes in the error curves following the maneuver time. Relate excessive changes in the drift rate to the requirement to perform evasive maneuvers inbound to a target while still requiring accurate navigation information for the return to the home airfield. If system alerts are noted during the flight, check for significant changes in the error rate curve following the time the alert is noted. Thoroughly investigate any INS alerts after the flight. Alerts that imply degraded accuracy and do not result in a change on the error curve or cannot be associated with a system failure should be related to the possibility of unnecessarily aborted sorties (false alarms). Relate the utility of the GPS/INS displays/controls, steering cues and integration within the aircraft to the usefulness of the INS as an aid for navigating to waypoints, the target position and later returning to the home airfield.

Analyze the recorded satellites and quality numbers for changes and drops, checking for corresponding degradation in the navigation accuracy. If the accuracy is degraded beyond the necessary accuracy, follow up with an investigation of the satellite geometry and the appropriateness of the individual satellite selections.

Repeat the procedure for the case of the GPS alone. The time base plot is not normally used for a position fixing system, however it may be useful to highlight the effects of satellite swaps and drop outs and of any maneuvers performed. Relate the performance to the necessity to perform the mission after the INS has failed or after an alert launch that did not allow for the alignment of the INS.

Analyze the data derived with the P code missing in the same fashion as the two previous sets of data. Relate the data to the necessity to perform the mission after the P code is dropped or when it is not available due to operational constraints.

Reduce and analyze the INS alone data identically to the process outlined in the INS test procedures.

### 3.3.3.7. Data Cards

A sample data card is provided as card 51.

CARD NUMBER ___ TIME ___ PRIORITY L/M/H

DYNAMIC NON-MANEUVERING POSITION ACCURACY

[AFTER PERFORMING THE INITIALIZATION AND ALIGNMENT TEST, SELECT A NAVIGATION MODE, START THE STOP WATCH AND RECORD THE LATITUDE AND LONGITUDE AND SATELLITE DATA. AFTER TAKEOFF, SET ___KIAS, CLIMB TO ____ FEET MSL AND BEGIN NORMAL EN ROUTE NAVIGATION. RECORD THE GPS/INS AND PORTABLE GPS DATA AT FIVE MINUTE INTERVALS. RECORD AS NOTES SYSTEM ALERTS AND MANEUVERS ABOVE 1.5G, 30° ANGLE OF BANK, 20° OF PITCH OR 50 KIAS OF AIRSPEED CHANGE WITH TIME AS REQUIRED. RECORD QUALITATIVE COMMENTS CONCERNING UTILITY FOR NON-MANEUVERING FLIGHT OF NAVIGATION DISPLAYS, STEERING CUES AND NAVIGATION ACCURACY. RECORD DATA BEFORE SHUTDOWN.]

SURVEYED ALIGNMENT LOCATION _____ _____

DISPLAYED WHEN SELECTED _____ _____

CONFIGURATION: GPS ON ___ INS ON ___ BOTH ON ___

P CODE: YES / NO

SATELLITES IN USE/QUALITY NUMBERS:

TOTAL FIX QUALITY NUMBER _____

NOTES:

Card 51: Dynamic Non-maneuvering Position Accuracy Data Cards

CARD NUMBER ___

DYNAMIC NON-MANEUVERING POSITION ACCURACY

| TIME | HAND-HELD GPS POSITION/SPACE POSIT FIX IF APPLICABLE/ALT/ COURSE/GROUND-SPEED | GPS/INS POSITION /ALT /COURSE/ GROUND-SPEED | SATELLITES/ QUALITY NUMBERS | TOTAL FIX QUALITY NUMBER | NOTES: |
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Card 51: Dynamic Non-maneuvering Position Accuracy Data Cards (Continued)

CARD NUMBER ___

DYNAMIC NON-MANEUVERING POSITION ACCURACY

SURVEYED SHUTDOWN LOCATION _____ _____

ELAPSED TIME AT SHUT DOWN _____

DISPLAYED AT SHUTDOWN _____ _____

QUALITATIVE COMMENTS CONCERNING UTILITY DURING NON-MANEUVERING FLIGHT OF NAVIGATION DISPLAYS/CONTROLS:

GPS/INS OR GPS ALONE STEERING CUES:

NON-MANEUVERING ACCURACY:

Card 51: Dynamic Non-maneuvering Position Accuracy Data Cards (Continued)